Design and Operation of the Pulsed Magnets at the Dresden High Magnetic Field Laboratory

Sergei Zherlitsyn

HLD.

EMFL
European Magnetic Field Laboratory

SFB 1143

Partner von DRESDEN concept
exzellenz-dresden.de

HZDR
HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF

MT25, Amsterdam, 2017

Outline

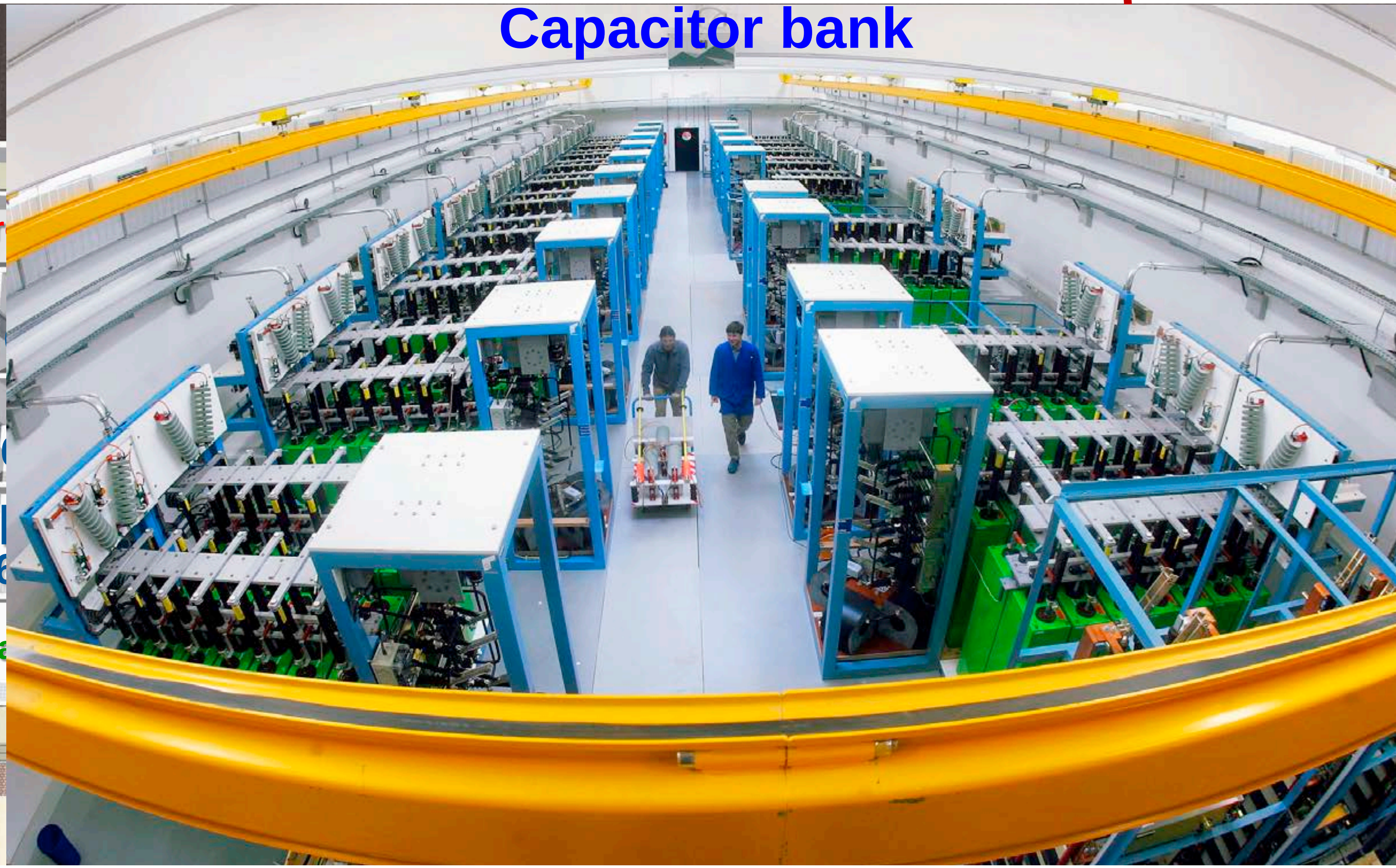
- **Non-destructive Pulsed Magnets:**

  - current status of the pulsed-magnet program
  at the HLD;
  - operational magnets,
  state of the art, recent improvements,
  and future developments;
  - scientific highlight

- **Summary**

10 pulsed-field cells, two capacitor banks

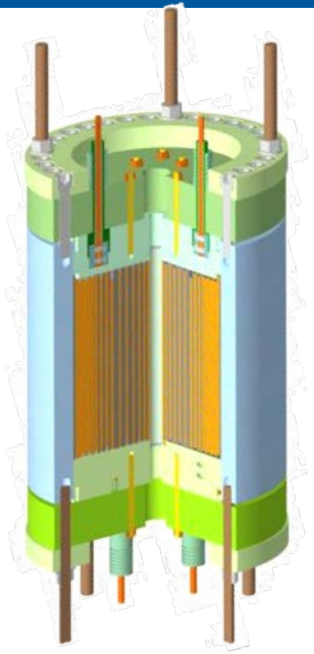
The infrastructure

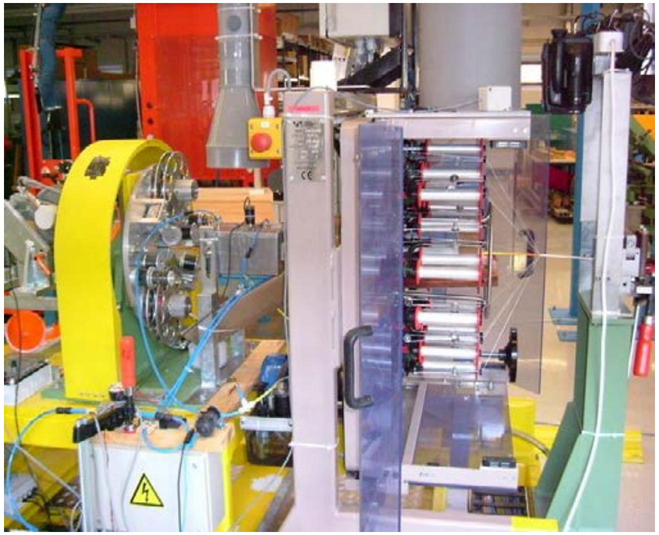


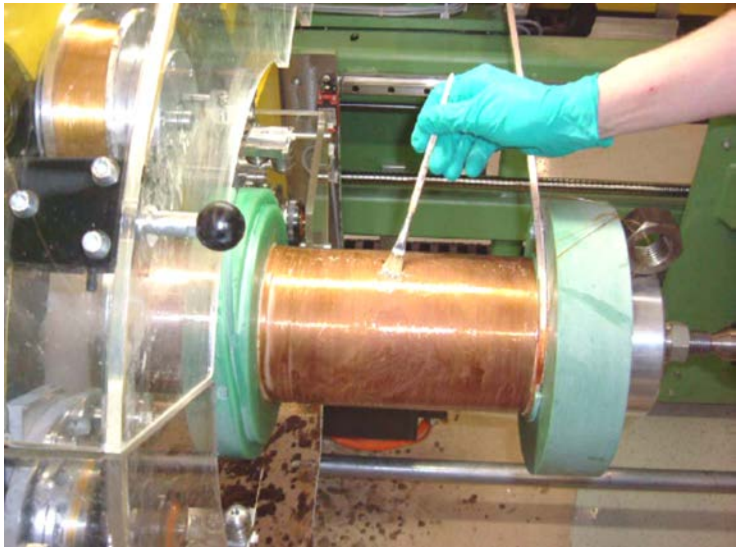
Capacitor bank

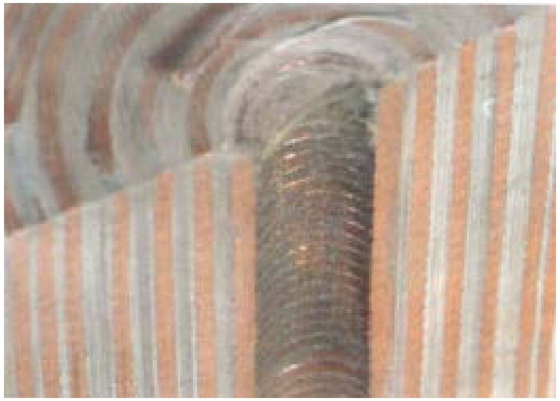
E_{max} = 50 MJ, U_{max} = 24 kV, I_{max} = 375 kA, P_{max} = 5 GW

Magnet design and in-house production









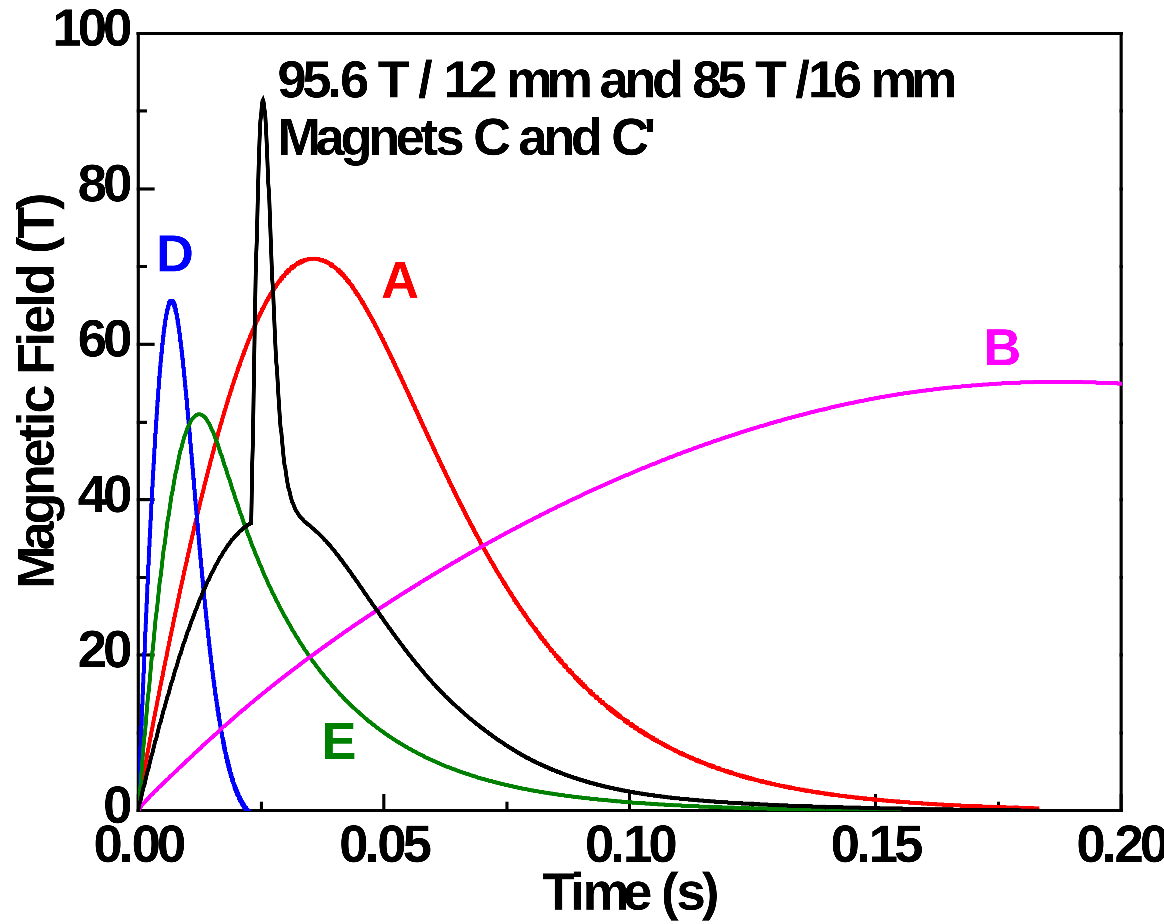
Pulsed-field magnets at the HLD

- Magnets A:
  70 and 65 T/ 150 ms/ 24 mm bore with and without cooling channels

- Magnets C and C’
  95 and 85 T in 12 or 16 mm

- Magnets D, E:
  65(50) T / 20 (100) ms
  20(24) mm

- Magnet B:
  60 T / 1500 ms / 40 mm (in stock)



Total amount of pulses ~ 40 000 since 2007

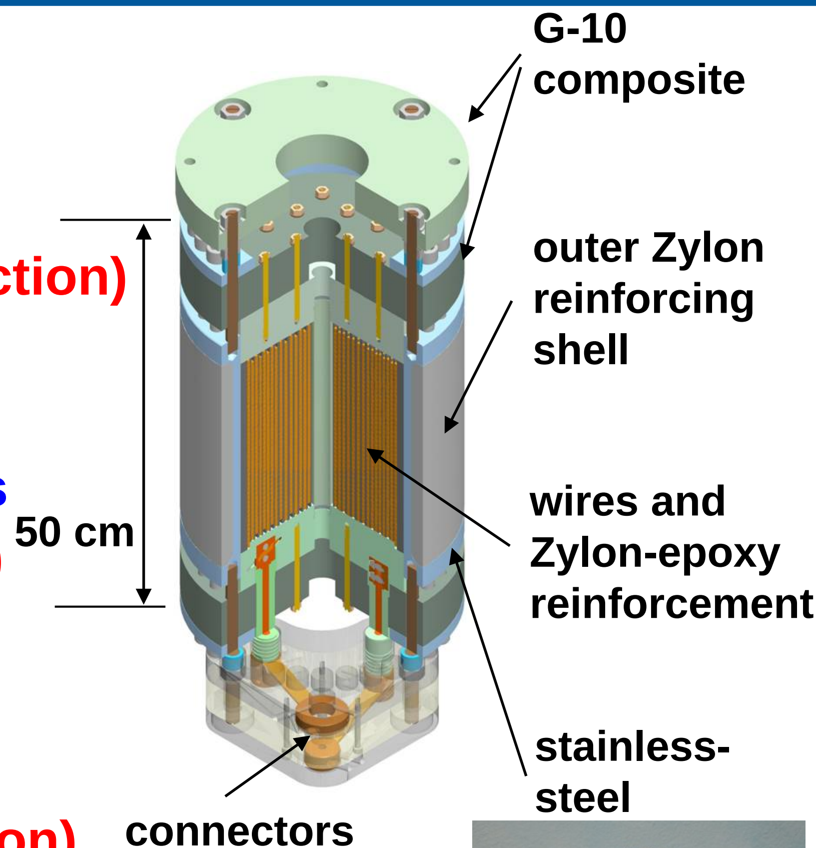
Pulsed magnets at the HLD

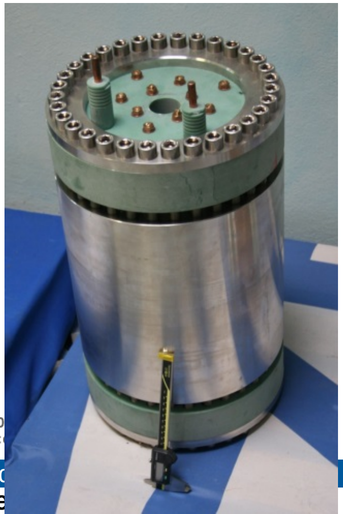
1) 8.6 MJ mono-coils with 24 mm bore, 65 -70 T, rise time 33 ms, whole pulse duration ~ 150 ms;
(4 magnets are in operation, 2 in production)

2) 1 MJ magnets with 20 or 24 mm bore, 50 – 65 T, whole pulse duration ~ 25 ms
(4 magnets are in operation, 1 in stock)

3) 9.5 MJ dual-coil magnets with 12 and 16 mm bore for the fields 85 - 95 T
(1 magnet is in operation, 1 in production)

4) 40 MJ mono-coil (long-pulse), 55 T, rise time ~ 230 ms (1 in stock)

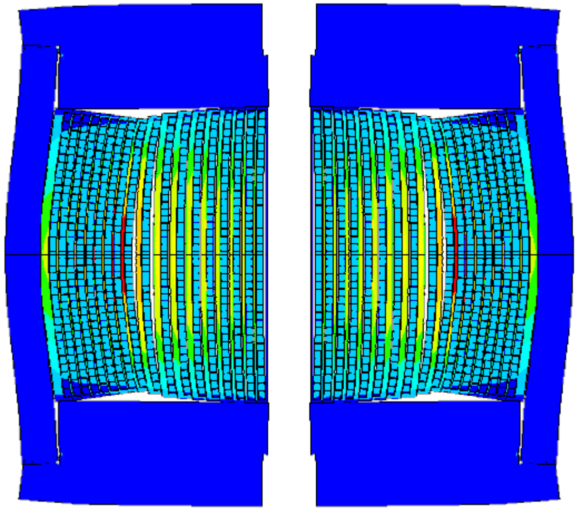




Typical magnet-life time is a few thousand pulses

HLD.

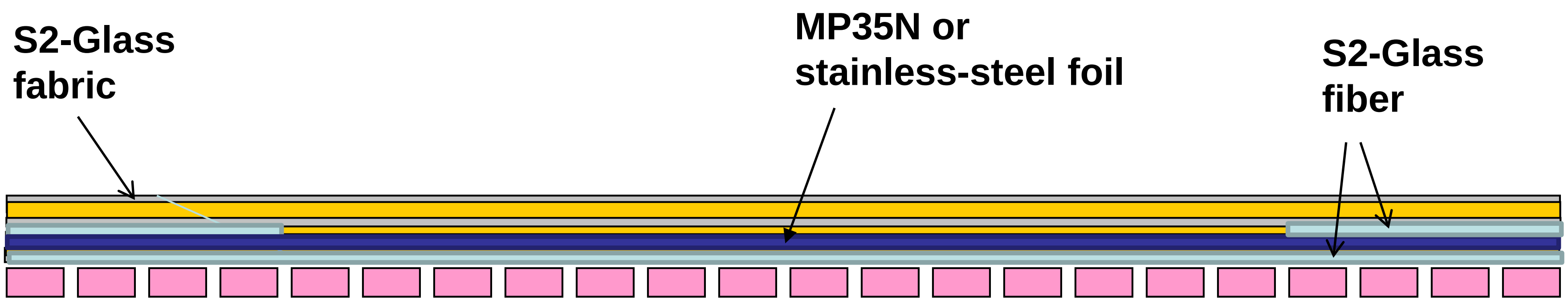
Challengies in magnet design



The most of the pulsed magnets are stress-limited : 4 GPa at 100 T

Magnet failure: shear stresses, reinforcement instability at the edges of the coil

A combination of S2 glass, stainless steel or MP35N foil (~0.1 mm thick) and Zylon fiber improve the reinforcement performance



Aim: Stress homogenization, additional safety

Solutions to improve the magnet performance:

1) **A new composition for the internal reinforcement:**
   S2 glass – stainless steel or MP35N foil (~0.1 mm thick) – Zylon

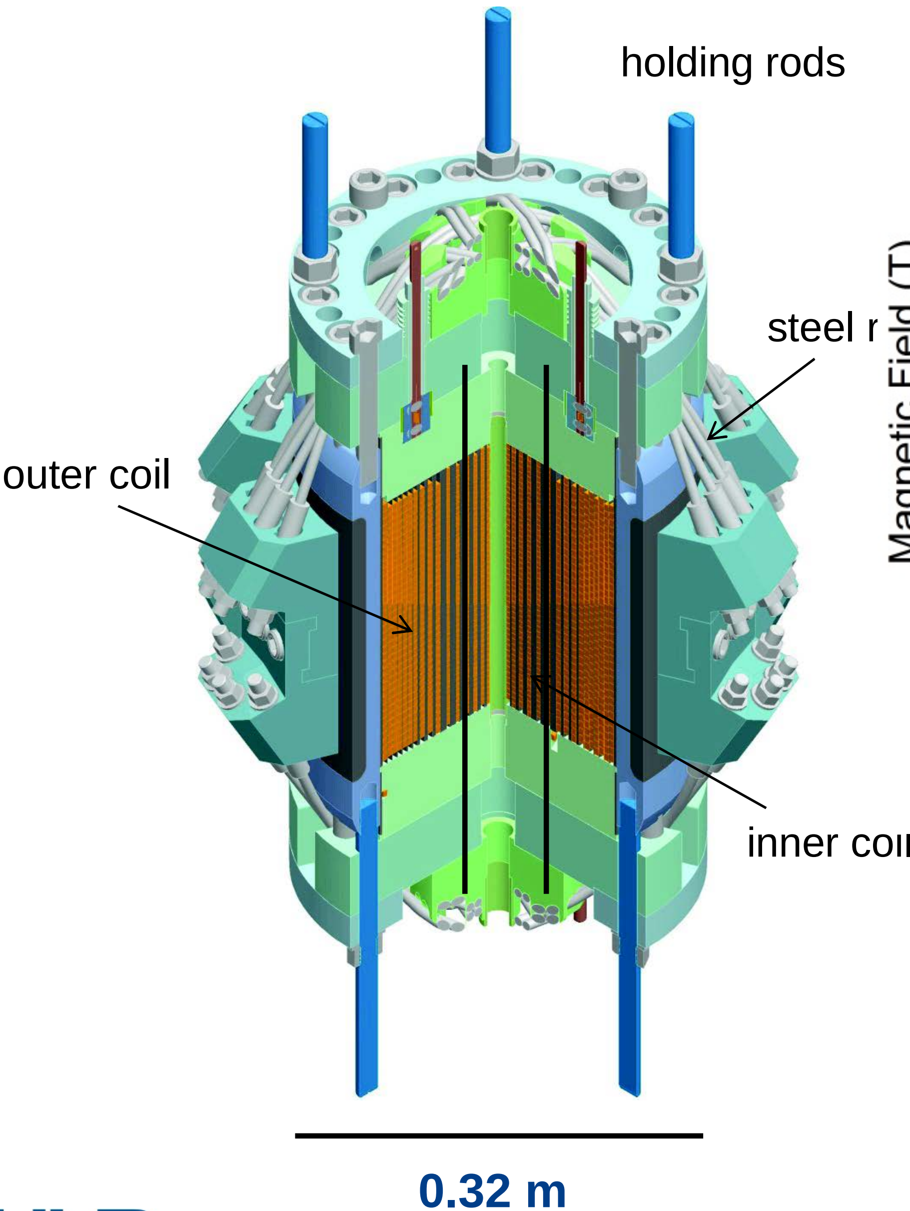
2) **No gap between the inner and outer coils**
   (rigid structure, drawback: longer cooling)

3) **The inner coil has only 4 layers (CuNb wire 6 x 4 mm^2)**
   (rigid structure, drawback: shorter pulse duration)

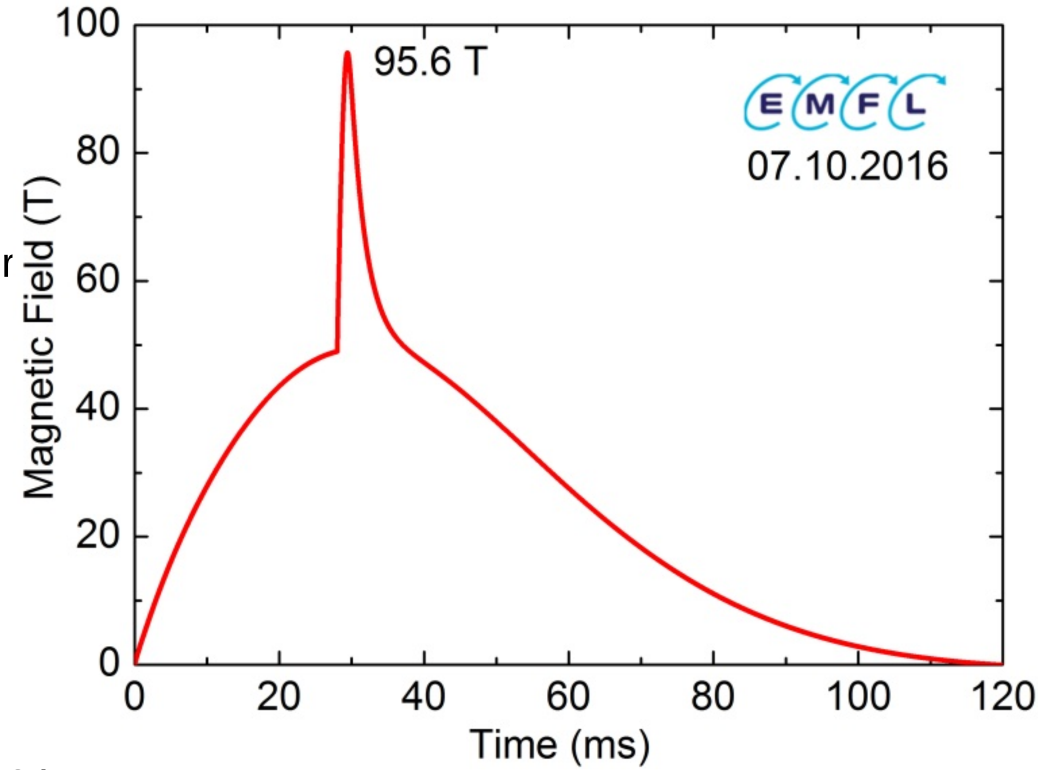
4) **The inner coil is slightly shorter (21 cm) than the outer one (25 cm) (better stabilization of layer transitions)**

Changes have been implemented in the magnet design

95 T and 85 T dual-coil



Energy: 0.9 MJ + 8.6 MJ

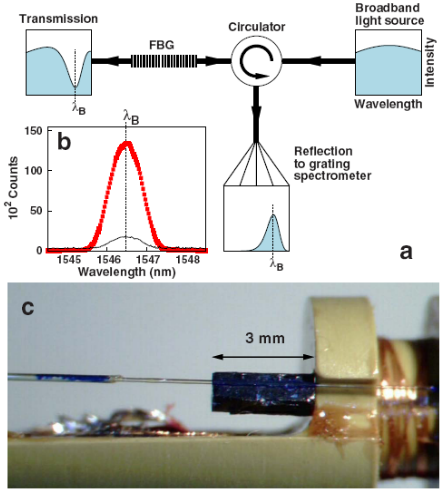


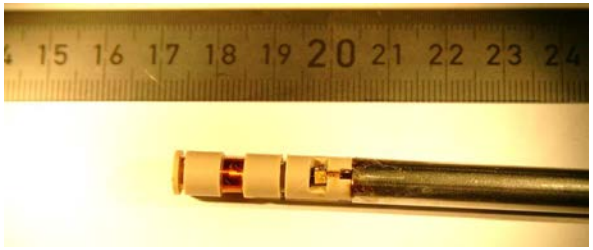
Calculated stress
in the reinforcement ~ 4 GPa

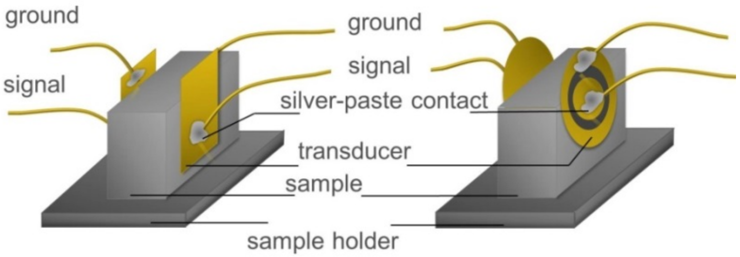
Available or feasible experimental techniques in 60-100 T

10 to 1000 ms is quasi-static; i.e., most of the experiments can be performed

- **Magnetization, magnetic susceptibility, dHvA Effect;**
- **DC/AC Transport, ShdH, Hall effect;**
- **FIR spectroscopy**
- **ESR and NMR;**
- **Ultrasound;**
- **Magnetostriction;**
- **Magnetocaloric effect;**
- **X-rays (in future, European XFEL)**

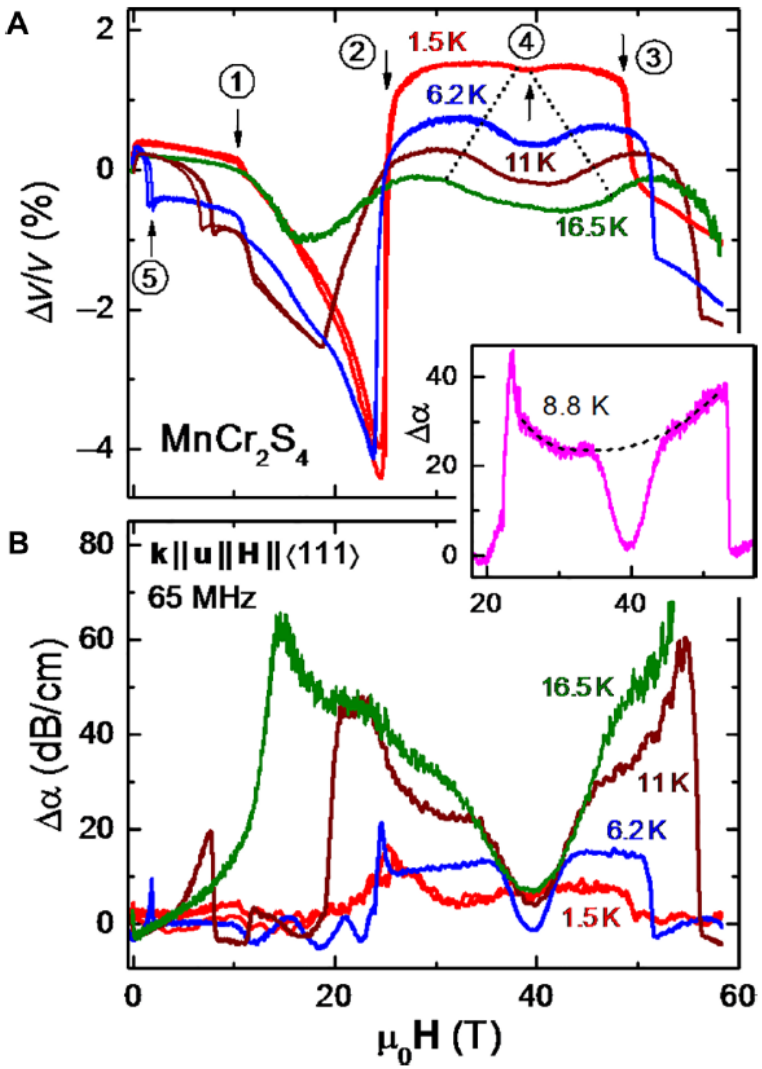


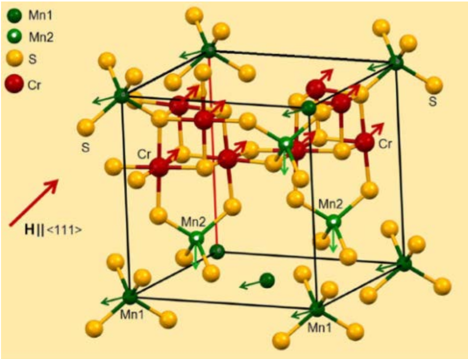




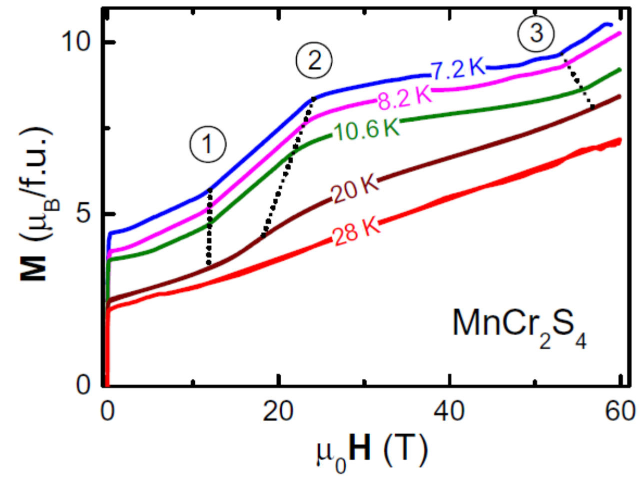
Supersolidity in frustrated magnet $MnCr_2S_4$

Ultrasound





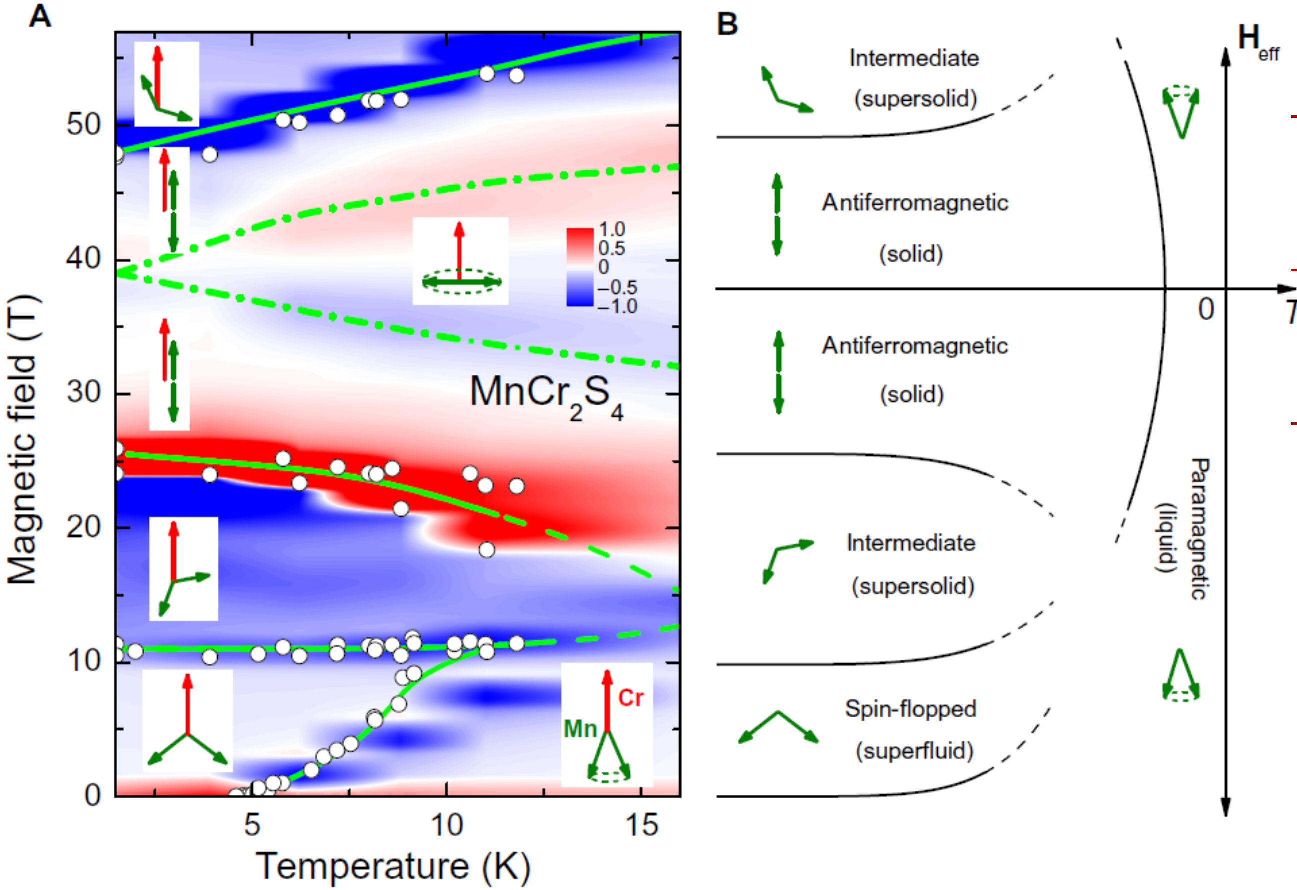
Magnetization



- The Mn–Cr exchange is compensated by *H*, and two-ion magnetoelastic coupling is effectively zero
- this field range (~ 40 T) may host complex spin structures or spin liquids

V. Tsurkan et al., Science Advances 3, e1601982 (2017)

H-T phase diagram and supersolidity



- Cr moments always remain parallel to *H*
- canted Mn spins rotate with respect to *H*
- supersolid phases occur in external *H* below and above the plateau region

- spin-lattice coupling is important to stabilize the supersolid phase and robust magnetization plateau

V. Tsurkan et al., Science Advances 3, e1601982 (2017)

Summary

- To perform reliable user operation in 95 T/12 mm, 85 T/16 mm, 70 T/24 mm magnets;
- To increase the peak field, reliability, and longevity of the pulsed magnets
- To provide 70 T user operation with rapid cooling magnets
- To address specific user demands related to pulsed magnets
- Increased winding capabilities: two winding machines, more magnets are produced now

Thank you for your attention !